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# **METHOD AND SYSTEM FOR COMPOSITING IMAGES WITH COMPENSATION FOR LIGHT FALLOFF**

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# METHOD AND SYSTEM FOR COMPOSITING IMAGES WITH COMPENSATION FOR LIGHT FALLOFF

## FIELD OF THE INVENTION

The invention relates generally to the field of digital image processing, and in particular to a technique for compositing multiple images into a panoramic image comprising a large field of view of a scene.

## BACKGROUND OF THE INVENTION

Conventional methods of generating panoramic images comprising a wide field of view of a scene from a plurality of images generally include the following steps: (1) an image capture step, where the plurality of images of a scene are captured with overlapping pixel regions; (2) an image warping step, where the captured images are geometrically warped onto a cylinder, sphere, or any environment map; (3) an image registration step, where the warped images are aligned; and (4) a blending step, where the aligned warped images are blended together to form the panoramic image. For an example of an imaging system that generates panoramic images, see May et al. USSN 09/224,547 filed December 31, 1998.

In the image capture step, the captured images typically suffer from light falloff. As described in many texts on the subject of optics (for example, M. Klein, *Optics*, John Wiley & Sons, Inc., New York, 1986, pp. 193-256), lenses produce non-uniform exposure at the focal plane when imaging a uniformly illuminated surface. When the lens is modeled as a thin lens, the ratio of the intensity of the light of the image at a point is described as $\cos^4$ of the angle between the optical axis, the lens, and the point in the image plane. This $\cos^4$ falloff does not include such factors as vignetting, which is a property describing the loss of light rays passing through an optical system.

In photographic images, this $\cos^4$ falloff generally causes the corners of an image to be darker than desired. The effect of the falloff is more severe for cameras or capture devices with a short focal length lens. In addition, flash photography will often produce an effect similar to falloff if the subject is

centrally located with respect to the image. This effect is referred to as flash falloff.

As described in US Patent 5,461,440 issued October 24, 1995 to Toyoda et al., it is commonly known that light falloff may be corrected by applying an additive mask to an image in a log domain or a multiplicative mask to an image in the linear domain. This conventional $\cos^4$ based mask is solely dependent upon a single parameter: the focal length of the imaging system. Also, images with flash falloff in addition to lens falloff, may be compensated for by a stronger mask (i.e. a mask generated by using a smaller value for the focal length than one would normally use).

Gallagher et al. in USSN 09/293,197 filed April 16, 1999 describe a variety of methods of selecting the parameter used to generate the falloff compensation mask. For example, in this conventional teaching the parameter could be selected in order to simulate the level of falloff compensation that is naturally performed by the lens of the optical printer. Additionally, the parameter could be determined interactively by an operator using a graphical user interface (GUI), or the parameter could be dependent upon the film format (APS or SUC) or the sensor size. Finally, they teach a simple automatic method of determining the parameter.

Gallagher in USSN 09/626,882 filed July 27, 2000 describes a method of automatically determining a level of light falloff in an image. This method does not misinterpret image discontinuities as being caused by light falloff, as frequently happens in the other methods.

In panoramic imaging systems, any of the aforementioned methods of light falloff compensation could be used to compensate for the light falloff present in each source image. However, there would be a problem with using any of these methods directly. Since all of the current light falloff compensation methods are applicable to single images, any errors in the falloff compensation for each source image could be magnified when the composite image is formed.

Therefore, there exists a need in the art for a method of compensating for light falloff in multiple images that are intended to be combined into a composite image.

## SUMMARY OF THE INVENTION

The need is met according to the present invention by providing a method and system for producing a composite digital image that includes providing a plurality of partially overlapping source digital images having pixel values that are linearly or logarithmically related to scene intensity; modifying the source digital images by applying to one or more of the source digital images a radial exposure transform to compensate for exposure falloff as a function of the distance of a pixel from the center of the digital image to produce adjusted source digital images; and combining the adjusted source digital images to form a composite digital image.

## ADVANTAGES

The present invention has the advantage of simply and efficiently matching source digital images having light falloff characteristics such that the light falloff is compensated prior to the compositing step.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram illustrating a digital image processing system suitable for practicing the present invention;

Fig 2 illustrates in block diagram form, the method of forming a composite image from at least two source images, at least one source image being compensated for light falloff;

Fig. 3 illustrates in block diagram form, one embodiment of the present invention;

Figs. 4A and 4B illustrate the overlap regions between source images;

Figs. 5A and 5B illustrate in block diagram form, the step of providing source digital images to the present invention;

Fig. 6 is a diagram of the relationship between the focal length, pixel position, and light falloff parameter in one of the source digital images;

Fig. 7 is a diagram of the relationship between the focal length, pixel position, and light falloff parameter in two of the source digital images;

Fig. 8 is a diagram of the process of modifying the source digital image to compensate for light falloff;

Fig. 9 is a plot of the pixel values in the overlap region of the second source digital versus the pixel values of the overlap region of the first source digital image;

Fig. 10 is a plot of the pixel values in the overlap region of the second source digital image versus the pixel values of the overlap region of the first source digital image;

Fig. 11 is a diagram of the process of combining images to form a composite image;

Fig. 12 illustrates in block diagram form, an embodiment of the present invention further including the step of transforming the composite image into an output device compatible color space; and

Figs. 13A and 13B are diagrams of image data and metadata contained in a source image file.

## DETAILED DESCRIPTION OF THE INVENTION

The present invention will be described as implemented in a programmed digital computer. It will be understood that a person of ordinary skill in the art of digital image processing and software programming will be able to program a computer to practice the invention from the description given below. The present invention may be embodied in a computer program product having a computer readable storage medium such as a magnetic or optical storage medium bearing machine readable computer code. Alternatively, it will be understood that the present invention may be implemented in hardware or firmware.

Referring first to Fig. 1, a digital image processing system useful for practicing the present invention is shown. The system generally designated **10**, includes a digital image processing computer **12** connected to a network **14**. The digital image processing computer **12** can be, for example, a Sun Sparcstation, and the network **14** can be, for example, a local area network with sufficient capacity to handle large digital images. The system includes an image capture device **15**, such as a high resolution digital camera, or a conventional film camera and a film digitizer, for supplying digital images to network **14**. A digital image store **16**, such as a magnetic or optical multi-disk memory, connected to network **14** is provided for storing the digital images to be processed by computer **12** according to the present invention. The system **10** also includes one or more display devices, such as a high resolution color monitor **18**, or hard copy output printer **20** such as a thermal or inkjet printer. An operator input, such as a keyboard and track ball **21**, may be provided on the system.

Referring next to Fig. 2, at least two overlapping source digital images are provided **200** to the processing system **10**. The source digital images can be provided by a variety of means; for example, they can be captured from a digital camera, extracted from frames of a video sequence, scanned from hardcopy output, or generated by any other means. The pixel values of at least one of the source digital images are modified **202** by a radial exposure transform so that any light falloff present in the source digital images is compensated, yielding a set of adjusted source digital images. A radial exposure transform refers to a transformation that is applied to the pixel values of a source digital image, the transformation being a function of the distance from the pixel to the center of the image. The adjusted source digital images are then combined **204** by a feathering scheme, weighted averages, or some other blending technique known in the art, to form a composite digital image **206**.

Referring next to Fig. 3, according to an alternative embodiment of the present invention, at least two overlapping source digital images are provided **300** to the processing system **10**. The pixel values of at least one of the source digital images are modified **302** by a radial exposure transform so that any light

falloff present in the source digital images is compensated. In addition, the pixel values of at least one of the source digital images are modified **304** by a linear exposure transform so that the pixel values in the overlap regions of overlapping source digital images are similar. A linear exposure transform refers to a transformation that is applied to the pixel values of a source digital image, the transformation being linear with respect to the scene intensity values at each pixel. The radial exposure transform and the linear exposure transform can be applied to the same source digital image, or to different source digital images. Also, the modification steps **302** and **304** can be applied in any order. Once either or both of the modification steps are completed, they yield adjusted source digital images. The adjusted source digital images are then combined **306** by a feathering scheme, weighted averages, or some other blending technique known in the art, to form a composite digital image **308**.

Referring next to Figs. 4A and 4B, the at least two source digital images **400** overlap in overlapping pixel regions **402**.

Referring next to Fig. 5A, according to a further embodiment of the present invention, the step **200** of providing at least two source digital images further comprises the step **504** of applying a metric transform **502** to a source digital image **500** to yield a transformed source digital image **506**. A metric transform refers to a transformation that is applied to the pixel values of a source digital image, the transformation yielding transformed pixel values that are linearly or logarithmically related to scene intensity values. In instances where metric transforms are independent of the particular content of the scene, they are referred to as scene independent transforms.

Referring next to Fig. 5B, in one embodiment, the step of applying the metric transform **504** includes applying a matrix transformation **508** and a gamma compensation lookup table **510**. In one example of such an embodiment, a source digital image **500** was provided from a digital camera, and contains pixel values in the sRGB color space. A metric transform **502** is used to convert the pixel values into nonlinearly encoded Extended Reference Input Medium Metric (ERIMM) (PIMA standard #7466, found on the World Wide Web at

http://www.pima.net/standards/it10/IT10_POW.htm), so that the pixel values are logarithmically related to scene intensity values.

Referring next to Fig. 6, we illustrate the relationship between the focal length $f$ **600**, pixel position $(u,v)$ **602**, and light falloff parameter $\theta$ **604** in one of the source digital images **608**. If the origin **606** is located at the center of the source digital image **608**, and if a uniformly illuminated surface parallel to the image plane is imaged through a thin lens, then the exposure $\mathrm{I}(u,v)$ received at pixel position $(u,v)$ is given by:

$$\mathrm{I}(u,v) = \mathrm{I}(0,0)\cos^4\left(\tan^{-1}\theta\right),$$

$$\theta = \frac{\sqrt{u^2+v^2}}{f},$$

where $\mathrm{I}(0,0)$ is the exposure falling on the center of the source digital image **608**, and the focal length $f$ **600** is measured in terms of pixels.

Referring next to Fig. 7, we illustrate two source digital images **700** and **702** that overlap in an overlapping pixel region **704**. The center **706** of source digital image **700** is located at the image center, and its local coordinate system is defined by positions $(u,v)$. The center **708** of source digital image **702** is located at the image center, and its local coordinate system is defined by positions $(x,y)$. The focal length used in the capture of source digital images **700** and **702** is given by $f$ **710** (in pixels). Consider a point **714** located in the overlapping pixel region **704**. If the coordinates of point **714** are given by $(u_i,v_i)$ in image **700**, and by $(x_i,y_i)$ in image **702**, and if a uniformly illuminated surface parallel to the image plane is imaged through a thin lens during both the captures of source digital image **700** and source digital image **702**, then the exposure $\mathrm{I}(u_i,v_i)$ received at point **714** in source digital image **700** is given by:

$$\mathrm{I}(u_i,v_i) = \mathrm{I}_1(0,0)\cos^4\left(\tan^{-1}\alpha_i\right),$$

$$\alpha_i = \frac{\sqrt{u_i^2+v_i^2}}{f},$$

where $I_1(0,0)$ is the exposure falling on the center of the source digital image **700**. The exposure $I(x_i, y_i)$ received at point **714** in source digital image **702** is given by:

$$I(x_i, y_i) = I_2(0,0)\cos^4\left(\tan^{-1}\beta_i\right),$$

$$\beta_i = \frac{\sqrt{x_i^2 + y_i^2}}{f},$$

where $I_2(0,0)$ is the exposure falling on the center of the source digital image **702**.

The point **714** in the overlapping pixel region **704** when considered as a point in the source digital image **700**, corresponds to the same scene content as if it were considered a point in the source digital image **702**. Therefore, if the overall exposure level of each source digital image **700** and **702** is the same, then the light falloff can automatically be determined without the knowledge of the focal length. (Note that if the focal length is known, the amount of light falloff is readily determined by the aforementioned formula). Consider that the exposure value recorded at point **714** in source digital image **700** is $I_i'$, and the exposure value recorded at point **714** in source digital image **702** is $I_i''$. Then, the following relation must hold:

$$\frac{I_i''}{\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2 + y_i^2}\right)\right)} = \frac{I_i'}{\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2 + v_i^2}\right)\right)}.$$

Since $I_i'$, $I_i''$, $u_i$, $v_i$, $x_i$, and $y_i$ are known, the focal length $f$ **710** can be found by identifying the root of the function:

$$g(f) = I_i'' \cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2 + v_i^2}\right)\right) - I_i' \cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2 + y_i^2}\right)\right).$$

This root can be approximated by an iterative process, such as Newton's method; see J. Stewart, "Calculus", 2nd Ed., Brooks/Cole Publishing Company, 1991, p. 170. Once the focal length $f$ **710** has been found, we know enough information to compensate for light falloff without having to identify the falloff parameter as described in one of the aforementioned light falloff compensation techniques.

Even though the focal length can be estimated from the pixel values of a single point **714** in the overlapping pixel region **704** of the source digital images **700** and **702**, multiple points in the overlapping pixel region can be used to provide a more robust estimate. Consider $n$ points in the overlapping pixel region **704**, where $n > 1$. Let these points have coordinates $(u_i, v_i)$, $i = 1 \ldots n$ in source digital image **700**, and coordinates $(x_i, y_i)$, $i = 1 \ldots n$ in source digital image **702**. Consider that the exposure value recorded at the $i^{\text{th}}$ point in source digital image **700** is $I_i'$, and the exposure value recorded at the $i^{\text{th}}$ point in source digital image **702** is $I_i''$. Now, the aforementioned relation must hold for each point in the overlapping pixel region **704**. Therefore, the focal length $f$ **710** can be found by minimizing some error measure. A typical error measure is sum of squared errors (SSE). Using SSE, the following function would be minimized:

$$r(f) = \sum_{i=1}^{n}\left[I_i'' \cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2+v_i^2}\right)\right) - I_i' \cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2+y_i^2}\right)\right)\right]^2 .$$

The minimum of $r(f)$ can be found by one of a variety of different techniques; for example, nonlinear least squares techniques such as the Levenberg-Marquardt methods (Fletcher, "Practical Methods of Optimization", 2nd Ed., John Wiley & Sons, 1987, pp. 100-119), or line search algorithms (Fletcher, pp. 33-40).

All of the aforementioned formulas and equations can be applied when the image pixel values are proportional to the exposure values falling onto the image planes. If image pixel values are proportional to the logarithm of the exposure values (as is the case if the image pixel values are encoded in the nonlinear encoding of ERIMM), then all of the aforementioned formulas must be modified to replace $\cos^4(\bullet)$ with $4\log(\cos(\bullet))$, where $\bullet$ indicates the argument of the cosine function.

In some instances, the overall exposure level of each source digital image **700** and **702** can differ. In these cases, the light falloff and the factor describing the overall difference in exposure levels can be simultaneously determined automatically without the knowledge of the focal length; however,

two distinct points in the overlapping pixel region **704** are required. Copending USSN _______ (EK Docket 83516/THC) filed by Cahill et al. November 5, 2001, details a technique for automatically determining the factor describing overall difference in exposure levels between multiple images, but that technique may not be robust if there is any significant falloff on at least one of the source images. Consider that the exposure value recorded at the $i^{\text{th}}$ point in the overlapping pixel region of source digital image **700** is $I_i'$, and the exposure value recorded at the corresponding point of source digital image **702** is $I_i''$, and that $i \geq 2$. Then, the following relation must hold:

$$\frac{I_i''}{\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2+y_i^2}\right)\right)} = \frac{hI_i'}{\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2+v_i^2}\right)\right)},$$

for $i = 1 \ldots n$, where $h$ is the factor describing the overall difference in exposure levels. Since $I_i'$, $I_i''$, $u_i$, $v_i$, $x_i$, and $y_i$ are known, the focal length $f$ and the exposure factor $h$ can be found by minimizing some error measure. A typical error measure is sum of squared errors (SSE). Using SSE, the following function would be minimized:

$$r(f,h) = \sum_{i=1}^{n}\left[I_i''\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2+v_i^2}\right)\right) - hI_i'\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2+y_i^2}\right)\right)\right]^2.$$

The minimum of $r(f,h)$ can be found by one of a variety of different nonlinear least squares techniques, for example, the aforementioned Levenberg-Marquardt methods.

As in the case where the overall exposure characteristics of the source images are the same, if the image pixel values are not proportional to exposure values, but rather to the logarithm of the exposure values, the above relation becomes:

$$I_i'' - 4\log\left(\cos\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2+y_i^2}\right)\right)\right) = h + I_i' - 4\log\left(\cos\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2+v_i^2}\right)\right)\right),$$

and the corresponding function to minimize is:

$$r(f,h)=\sum_{i=1}^{n}\left[I_i'' - I_i' - h + 4\log\left(\cos\left(\tan^{-1}\left(f^{-1}\sqrt{u_i^2+v_i^2}\right)\right)\right) - 4\log\left(\cos\left(\tan^{-1}\left(f^{-1}\sqrt{x_i^2+y_i^2}\right)\right)\right)\right]^2$$

Referring next to Fig. 8, the process of modifying the source digital image **800** to compensate for light falloff is illustrated. A light falloff compensation mask **802** is generated and applied to the source digital image to form the adjusted source digital image **804**. The compensation mask **802** can either be added to or multiplied by the source image **800** to form the adjusted source digital image **804**. If the source image pixel values are proportional to exposure values, the value of the mask at pixel position $(u,v)$ (with $(0,0)$ being the center of the mask) is given by:

$$\text{mask}(u,v)=\left[\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u^2+v^2}\right)\right)\right]^{-1},$$

and the mask **802** is multiplied with the source digital image **800** to form the adjusted source digital image **804**. If the source digital image pixel values are proportional to the logarithm of the exposure values, the value of the mask at pixel position $(u,v)$ (with $(0,0)$ being the center of the mask) is given by:

$$\text{mask}(u,v)=-4\log\left(\cos^4\left(\tan^{-1}\left(f^{-1}\sqrt{u^2+v^2}\right)\right)\right),$$

and the mask **802** is added to the source digital image **800** to form the adjusted source digital image **804**.

Referring next to Fig. 9, we show a plot **900** of the pixel values in the overlap region of the second source digital **902** versus the pixel values of the overlap region of the first source digital image **904**. If the pixel values in the overlap regions are identical, the resulting plot would yield the identity line **906**. In the case that the difference between the pixel values of the two images is a constant, the resulting plot would yield the line **908**, which differs at each value by a constant amount **910**. The step **304** of modifying at least one of the source digital images by a linear exposure transform would then comprise applying the constant amount **910** to each pixel in the first source digital image. One example of when a linear exposure transform would be constant is when the pixel values of

the source digital images are in the nonlinearly encoded Extended Reference Input Medium Metric. The constant coefficient of the linear exposure transform can be estimated by a linear least squares technique (see Lawson et al., Solving Least Squares Problems, SIAM, 1995, pp. 107-133) that minimizes the error between the pixel values in the overlap region of the second source digital image and the transformed pixel values in the overlap region of the first source digital image.

In another embodiment, the linear exposure transforms are not estimated, but rather computed directly from the shutter speed and F-number of the lens aperture. If the shutter speed and F-number of the lens aperture are known (for example, if they are stored in meta-data associated with the source digital image at the time of capture), they can be used to estimate the constant offset between source digital images whose pixel values are related to the original log exposure values. If the shutter speed (in seconds) and F-number of the lens aperture for the first image are $T_1$ and $F_1$ respectively, and the shutter speed (in seconds) and F-number of the lens aperture for the second image are $T_2$ and $F_2$ respectively, then the constant offset between the log exposure values is given by:

$$\log_2\left(F_2^2\right)+\log_2(T_2)-\log_2\left(F_1^2\right)-\log_2(T_1),$$

and this constant offset can be added to the pixel values in the first source digital image.

Referring next to Fig. 10, we show a plot **1000** of the pixel values in the overlap region of the second source digital **1002** versus the pixel values of the overlap region of the first source digital image **1004**. If the pixel values in the overlap regions are identical, the resulting plot would yield the identity line **1006**. In the case that the difference between the two images is a linear transformation, the resulting plot would yield the line **1008**, which differs at each value by an amount **1010** that varies linearly with the pixel value of the first source digital image. The step **304** of modifying at least one of the source digital images by a linear exposure transform would then comprise applying the varying amount **1010** to each pixel in the first source digital image. One example of when a linear exposure transform would contain a nontrivial linear term is when the pixel values

of the source digital images are in the Extended Reference Input Medium Metric. The linear and constant coefficients of the linear exposure transform can be estimated by a linear least squares technique as described above with reference to Fig. 9.

Referring next to Fig. 11, the adjusted source digital images **1100** are combined in the overlap region **1104** by a feathering scheme, weighted averages, or some other blending technique known in the art, to form a composite digital image **1106**. In one embodiment, a pixel **1102** in the overlap region **1104** is assigned a value based on a weighted average of the pixel values from both adjusted source digital images **1100**; the weights are based on its composite digital image **1106** to the edges of the adjusted source digital images **1100**.

Referring next to Fig. 12, according to a further embodiment of the present invention, at least two source digital images are provided **1200** to the processing system **10**. The pixel values of at least one of the source digital images are modified **1202** by a radial exposure transform so that any light falloff present in the source digital images is compensated, yielding a set of adjusted source digital images. The adjusted source digital images are then combined **1204** by a feathering scheme, weighted averages, or some other blending technique known in the art, to form a composite digital image **1206**. The pixel values of the composite digital image are then converted into an output device compatible color space **1208**. The output device compatible color space can be chosen for any of a variety of output scenarios; for example, video display, photographic print, ink-jet print, or any other output device.

Referring finally to Figs. 13A and 13B, at least one of the source digital image files **1300** may contain meta-data **1304** in addition to the image data **1302**. Such meta-data **1304** could include the metric transform **1306**, the shutter speed **1308** at which the image was captured, the f-number **1310** of the aperture when the image was captured, the focal length **1312** when the image was captured, a flash indicator **1314** to indicate the use of the flash when the image was captured, or any other information pertinent to the pedigree of the source

digital image. The meta-data can be used to directly compute the linear transformations as described above.

The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the spirit and scope of the invention.

## PARTS LIST

| | |
|---|---|
| 10 | digital image processing system |
| 12 | digital image processing computer |
| 14 | network |
| 15 | image capture device |
| 16 | digital image store |
| 18 | high resolution color monitor |
| 20 | hard copy output printer |
| 21 | keyboard and trackball |
| 200 | provide source digital images step |
| 202 | modify source digital images step |
| 204 | combine adjusted source digital images step |
| 206 | composite digital image |
| 300 | provide source digital images step |
| 302 | modify source digital images with radial exposure transform step |
| 304 | modify source digital images with linear exposure transform step |
| 306 | combine adjusted source digital images step |
| 308 | composite digital image |
| 400 | source digital images |
| 402 | overlap regions |
| 500 | source digital image |
| 502 | metric transform |
| 504 | apply metric transform step |
| 506 | transformed source digital image |
| 508 | matrix transform |
| 510 | gamma compensation lookup table |
| 600 | focal length $f$ |
| 602 | point (u,v) |
| 604 | angle $\theta$ |
| 606 | image center |
| 608 | source digital image |
| 700 | source digital image |
| 702 | source digital image |
| 704 | overlapping pixel region |
| 706 | image center |

| | |
|---|---|
| 708 | image center |
| 710 | focal length *f* |
| 714 | point |
| 800 | source digital image |
| 802 | light falloff compensation mask |
| 804 | adjusted source digital image |
| 900 | plot of relationship between pixel values of overlap region |
| 902 | second image values |
| 904 | first image values |
| 906 | identity line |
| 908 | actual line |
| 910 | constant offset |
| 1000 | plot of relationship between pixel values of overlap region |
| 1002 | second image values |
| 1004 | first image values |
| 1006 | identity line |
| 1008 | actual line |
| 1010 | linear offset |
| 1100 | adjusted source digital images |
| 1102 | pixel |
| 1104 | overlap region |
| 1106 | composite digital image |
| 1200 | provide source digital images step |
| 1202 | modify source digital images step |
| 1204 | combine adjusted source digital images step |
| 1206 | composite digital image |
| 1208 | transform pixel values step |
| 1300 | source digital image file |
| 1302 | image data |
| 1304 | meta-data |
| 1306 | metric transform |
| 1308 | shutter speed |
| 1310 | f-number |
| 1312 | focal length |
| 1314 | flash indicator |